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**OPTICAL ACTIVITY IN SAPONIFIED ORGANIC MATTER
ISOLATED FROM THE INTERIOR OF THE ORGUEIL METEORITE**

UNPUBLISHED PRELIMINARY DATA

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by

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INTRODUCTION

An optically active fraction was obtained by saponification of solvent extracts from a stone of the Orgueil carbonaceous meteorite. The surface layer of this stone was removed with a high speed, dental type drill prior to extraction to ensure the exclusion of possible contaminations from the meteorite surfaces. The extraction and saponification was conducted in a newly built, special laboratory at the University of California, not yet used for the study of biological materials and containing no stopcock grease or other possible contaminants. (The saponified meteorite extracts showed a small but well reproducible levo-rotation. Two saponified fractions obtained by the identical procedure from smaller fragments of two other stones of the Orgueil meteorite showed very similar levo-rotation.) Saponified fractions obtained again by the same procedure from a dust sample in the museum where the three stones were kept, an old wax sample used for sealing a container holding meteorites in a different museum, ragweed pollen (Ambrosia elatior) grains, and soil were dextro-rotatory at the same wavelengths. Identical fractions obtained from a recent alga (Pelagophycus porra), naphthenic acids in petroleum and the Bruderheim non-carbonaceous meteorite were either slightly dextro-rotatory or showed no optical activity at the same wavelengths. The chemical composition of the optically active fractions was analyzed by infrared, ultraviolet and visible spectroscopy and thin layer chromatography. The thin layer chromatograms showed that the composition of the Orgueil meteorite extracts was wholly different

from the composition of saponified fractions that can be isolated by identical procedures from recent biological matter. /

Stones of the Orgueil meteorite shower fell at about 8 p.m. on May 14, 1864 near Orgueil and Campsas in France. It was discovered only a few weeks after the fall (1) that these stones contained significant quantities of organic matter, including hydrocarbons (2). Recent analyses (3, 4, 5, 6) revealed saturated and aromatic hydrocarbons, long chain fatty acids and what appear to be porphyrins. Microstructures resembling microfossils were observed in the stones (7, 8). These organized elements were mineralized with iron hydroxide, limonite, contained some chlorine (9) and left acid insoluble residues after HCl leaching. The residues contained compounds resembling ribonucleic acids and proteinaceous matter (10). The mineral composition of the Orgueil meteorite suggests that the parent body had an aqueous, low temperature, somewhat reducing and slightly alkaline environment (11), one which could have supported life processes. The meteorite contains approximately 20 per cent water (12) most of which appears to be non-terrestrial because of its significantly different deuterium/hydrogen ratio (13). The burnt crust of the stones, acquired during the passage through the earth's atmosphere, is only a few hundred microns thick (14). There is no mineralogical evidence that the stones were damaged by heat beneath the crust.

A spectropolarimetric examination was undertaken because optical rotation in organic molecules is generally regarded as evidence for biological origin. It should be noted in this connection that biological matter which has accumulated in and been preserved through the geological past on earth, such as petroleum and components of coal, still show optical rotation (15, 16) even though it may have been subjected to rather severe environments while lying buried in the rocks.

SAMPLES AND REAGENTS

Orgueil meteorite. Three Orgueil meteorite samples were obtained from the Montauban Museum, Montauban, Tarn et Garonne, France through the courtesy of Dr. A. Cavaillé. The museum records showed that these stones were kept continuously in the museum since May 26, May 29 and June 20, 1864, respectively, under glass bell jars. One of the samples

consisted of a rather large, dark-colored fragment of a stone (Figure 1), showing well developed fusion crust on one side. The other two samples consisted of smaller, dark colored fragments. All three samples showed some of the usual white crystalline material (epsomite) exposed on the surfaces. A careful examination of the fragments under a dissecting microscope showed no surface contaminations, such as paint marks, wax, varnish, shellac, etc. A detailed microscopic study of petrographic thin sections of several fragments showed no disruption of the original mineral-grain texture. This observation together with the fact that the water soluble meteorite mineral, epsomite, was still present, excludes the possibility that the interiors of these samples were contaminated by mechanical or solution processes.

Bruderheim meteorite. A 21.1 g sample of the Bruderheim non-carbonaceous meteorite, which fell in Canada in 1960, was obtained from Drs. G. Goles and R. Murthy of the University of California, San Diego. This control sample was taken from the interior of a complete stone, No. 42701B18, obtained originally from the University of Alberta, Canada. Almost the entire surface of the stone possessed a burnt crust. Bruderheim contains minerals of high temperature history only, therefore it is believed that it cannot contain indigenous biochemical compounds.

Museum dust. A 2.71 g sample of dust from the Montauban Museum was obtained from Dr. A. Cavaille. It consisted of microbiological matter, fragments of dry plant leaves, textile threads, granules of brick and mortar, etc. This dust accumulated through a period of years. This control sample is thought to be representative of the terrestrial biological contaminants which were present during the meteorite storage.

Museum wax. A 0.38 g sample of wax was obtained from Prof. J. Orcel of the Museum National d' Histoire Naturelle in Paris. This old wax sample was used in Paris to seal containers holding meteorites. It was chosen as a control because it might represent the general type of waxes with which the Orgueil meteorite could have been contaminated at various museums during storage.

Ragweed pollen. A 0.25 g sample of pollen was obtained from Dr. B. Siegel of the Brooklyn Jewish Hospital in New York to be used as a control. It has been claimed (17, 18) that organized elements are recent pollen contaminants, particularly ragweed, Ambrosia elatior,

pollen. If this claim is true it is conceivable that the bituminous matter in Orgueil might have been contaminated with biochemicals from pollen.

Marine algae. It has been suggested (7) that organized elements may morphologically resemble algae. A specimen of the large, multicellular and commonly available brown alga, Pelagophycus porra (a seaweed or kelp), was used as a control. A fresh sample was collected by one of the authors (B.N.) on the beach at the University of California in La Jolla, during heavy seas which washed the kelp ashore. A 30 g sample was used in this study.

Soil. An 11.5 g soil sample, another control, was obtained from an oak forest in Hartsdale, New York; it was collected by one of the authors (B.N.). This soil was apparently not affected by cultivation or other artificial processes. It is probable, of course, that the organic composition of the soil at the locations of the meteorite fall in 1864 was different from that of this control sample even though the latter was obtained from a climatic region not markedly dissimilar from the vicinity of the village of Orgueil. Such soils contain a wide range of biochemicals including many common classes of compounds.

Naphthenic acids. A refinery SO_2 extract of naphthenic acids, isolated from combined petroleum stocks, was obtained from Dr. Sol Silverman of the California Research Corporation in La Habra, California for the purpose of an additional control. 1 g portions of the sample were used in this study.

Solvents, chemicals and glassware. Only reagent or C.P. grade chemicals were used: benzene, methanol, water, ether, hydrochloric acid, potassium hydroxide and anhydrous sodium sulfate. All liquids, except ether, were freshly distilled prior to use through 12 or 16 inch distilling columns packed with glass beads or Raschig rings. Carbon tetrachloride used in infrared analysis and polarimetry was spectral grade. Ether was purified by chromatography on activated alumina (Woelm, neutral, Grade I) columns according to procedures described in the literature (19). Solvents accepted for use contained 0.0-0.4 mg residue /100 g solvent and exhibited no extraneous absorption effects on their infrared spectra. All glassware was acid cleaned with a mixture of hot 85% conc. H_2SO_4 and 15% conc. HNO_3 . No stopcock grease was used, and no plastic or rubber implements were in contact with the samples or solutions. Liquid samples were evaporated under a stream

of (water-pumped) nitrogen filtered through Matheson molecular sieve gas purifiers recommended for the removal of traces of oil and water. Blank runs, (i.e. procedure blanks) containing solvents only, but otherwise identical with the entire meteorite analytical procedure, were performed prior and parallel to all experiments.

Standards for thin-layer chromatography. The composition of the Orgueil optically active fractions was analyzed by comparison with identically prepared saponified fractions isolated from recent biological matter, with lipid fractions and pure compounds. The following standards were used in addition to brown algae, museum wax and naphthenic acids: (a) plants; saponified matter from purple sulfur bacteria (Chromatium sp.), bacteria found in marine muds (Saprospira grandis), moss (Polytrichum commune), fungus (Pholiota praecox), and the leaves of the flowering plant, banana palm (Musa sapientum); (b) animals; saponified matter from an anthozoa, sea anemone (Bunodes rigidus), excluding the tissues of the digestive tract, and non-saponified lipid extracts from beef brain and beef spleen. Chloroform rinse of one of the investigator's hands (B.N.) and a cold chloroform extract of the Orgueil meteorite served as two additional standards. The following pure compounds and element were used as standards on the thin layer plates; hydrocarbons; n-hexadecane (C_{16}), n-octadecane (C_{18}) and n-triacontane (C_{30}); elemental sulfur; amino acids; L- (+) glutamic acid, L- (-) leucine, glycine and DL - α - alanine; fatty acids; oleic (C_{18}), stearic (C_{18}), cerotic (C_{26}), α -methyl eicosanoic (C_{21}) and α -ethyl eicosanoic (C_{22}) acids. The last two compounds which are saturated, branched-chain fatty acids, were prepared during this study from malonic ester syntheses using 1-bromooctadecane, methyl iodide or ethyl iodide in a procedure similar to the method described by Bleyberg and Ulrich (20).

Standards for optical rotation measurements. The optical rotation of the samples was evaluated with reference to solvent blanks, and solutions in which different forms of sulfur were dissolved. Because the saponified fractions from Orgueil and controls were light brownish-yellow in color, dyes and colloidal sulfur were added to some of the blanks in an attempt to reproduce the sample absorptions in the visible spectral range. A mixture of two synthetic dyes consisting of a darkened sample of N-methyl aniline and of isatin trinitrophenyl ether in CCl_4 gave the best color match (Figure 2).

EXPERIMENTAL PROCEDURES

Sample preparation. One of the Orgueil stones was big enough for mechanical cleaning prior to extraction. Figure 1 shows this stone fragment (26.19 g) before its surface was drilled off with a modified "Port-a-dent" dental type, turbine drill, 5,000 to 200,000 rpm, manufactured by Pioneer Research and Development Company in Lemon Grove, California. In the present experiment nitrogen (water pumped and filtered through a Matheson molecular sieve gas purifier) was used to drive the turbine at 40 psi pressure. The turbine was covered with tape to exclude possible oil contaminations from bearings. The water jet customarily used in dental work was disconnected and it was assured that only a weak and diffuse part of the N_2 stream blew toward the sample. The drill bit was carefully washed with distilled chloroform prior to the experiment to remove possible lipid contaminations. (Chloroform washing was judged to be more effective than sterilization which only kills living organisms). The entire surface of the stone was removed by drilling. Following this, the stone was broken along planes of weakness, and then cleaned by drilling along the new surfaces to remove any extraneous matter that may have seeped in there. The stone weighed 22.34 g after its surface was removed. This stone and all other samples were pulverized, except controls which were received in powdered form. The kelp was homogenized in a Waring type blender.

Extraction and saponification The powdered Orgueil meteorite samples, 100-200 mesh, (11.13g, 11.49g and 22.05g respectively) and all controls were extracted in fritted glass thimbles for five hours in a Soxhlet apparatus with 100 ml of a benzene-methanol (6:4) solution. 2.9 g of KOH and 1 ml of water were added to the bottom flask of the apparatus to saponify carboxylic acid derivatives (e.g. esters) extracted from the sample in the thimble. At no time was the KOH in contact with the sample in the thimble. The saponified material was extracted by shaking with 50 ml water to which a 20 percent solution of HCl was added to acidify the separated aqueous extract. The acidified material was extracted with 25 ml of ether, which was then evaporated to dryness at room temperature under nitrogen. Next the residue was dissolved in CCl_4 for infrared and polarimetric measurements. The extraction and saponification procedure was identical to that described by Nagy and Bitz (5) for the isolation of fatty acids from the Orgueil

meteorite.

Infrared spectroscopy. A Perkin-Elmer Infracord, 137, spectrometer with NaCl optics was used to identify the saponified fractions. The CCl_4 solutions were run in 1.0 or 2.0 mm NaCl cavity cells. Comparison of infrared spectra of Orgueil and all control extracts with spectra of pure compounds and acids in the literature (21, 22) showed characteristic acid absorption features (Figures 3 and 4). The meteorite fractions showed a strong acid-carbonyl absorption at 5.85μ , shoulders at 3.3 and 3.7μ and a broad band at 10.7μ . These spectral features are generally regarded to be characteristic of carboxylic acids (21). In an earlier study (5) the identity of the acids in Orgueil was further substantiated by the preparation and spectra of carboxylic acid derivatives (methyl esters).

Ultraviolet and visible spectroscopy. A Beckman DK-2A spectrophotometer, equipped with 1 cm cells, was used to obtain the UV and visible spectra. One meteorite saponified fraction was analyzed in a Cary Model 15 spectrophotometer. Samples were examined in methanol (or occasionally in CCl_4 solutions in the visible range). The Orgueil acidic fractions showed absorption bands at 277, 262 and $220 \text{ m}\mu$ in the UV range. The ultraviolet spectra of naphthenic acids and of the lipid hydrolysates from Pelagophycus were run and showed variations from the Orgueil spectra (Figure 5). Agreement between the infrared spectra of these three samples (Figure 4) indicates only the presence of a common, general component group rather than a narrow class of compounds. The visible spectra of Orgueil saponifiable matter were characterized by the absence of absorption bands and by a general increase in absorption toward lower wavelengths. Hodgson (6) found that the visible spectra of the hexane-benzene eluates from silica gel columns of our non-saponifiable Orgueil fractions showed absorptions which resembled a petroleum porphyrin peak. However, dihydroporphyrins (common constituents of dust and recent biological contaminations) were absent, the detection limit being approximately 0.0002 ppm. This further emphasizes the lack of terrestrial contamination in the interior of the Orgueil meteorite.

Thin layer chromatography. The composition of the Orgueil saponified fractions was further examined by thin layer chromatography. The chromatograms were compared with those of the various standards. Thin layer plates spread with silica gel and magnesium silicate or calcium sulfate as the binder were heat activated at 120°C for twenty minutes and air cooled for thirty minutes before application of the samples with

a calibrated microsyringe. Plates were developed in lined chambers with two solvent systems differing in polarity; a chloroform-methanol-water mixture, and the less polar hexane-ether system. After air evaporation of the developing solvents, the plates were sprayed with rhodamine 6G, which under ultraviolet light stained the spots yellow or purple on a lighter purple background. Chromatograms photographed under ultraviolet light are shown in Figures 6A, b and c. Thin layer chromatography separates compounds on the basis of polarity rather than on structure. From the thin layer chromatography of the Orgueil saponified extracts, hydrocarbon, sulfur, and acidic fractions were evident. Individual components were scraped off the plates with a razor blade, eluted from the adsorbent, and identified by their characteristic infrared spectra. Corresponding areas on control thin layer plates were subjected to the same procedure. Certain spots present on four chromatograms of Orgueil were the fatty acids, but they represent only a minor percentage of the total and apparently are insufficient to cause the observed optical rotation of the saponified extract. Analysis and control experiments with amino acids, including thin layer chromatography using ninhydrin spray reagent and solubility tests, have shown the absence of amino acids in the Orgueil saponified fractions; consequently, the observed levo-rotation is not caused by these compounds. The composition of the Orgueil optically active fraction does not resemble the composition of museum wax, naphthenic acids, sulfur bacteria, bacteria from marine mud, brown algae, moss, fungus, palm leaves, sea anemone, beef brain, beef spleen, lipids from human hand, or synthetic mixtures of pure lipid compounds. Some of the usual recent biological lipids were absent in both saponified and cold chloroform extracts of Orgueil.

Optical rotation measurements. The saponified fractions from meteorites and controls dissolved in CCl_4 were measured with two different type instruments, two Rudolph photoelectric spectropolarimeters using xenon-mercury light sources, and a Rudolph visual polarimeter, modified by a photoelectric detection system. Cell lengths varied between 0.1 and 2.0 dm; a 1.0 dm cell was used most often. Measurements were made between 306 and 650 $\text{m}\mu$ wavelengths, however, no solution was found to be transparent below 353 $\text{m}\mu$. The samples (excluding one of the three Orgueil samples) were filtered through Millipore filters of 0.45 $\text{m}\mu$ pore size before the measurements. All three

of the instruments were calibrated with solvent blanks, and in addition one instrument was also calibrated with colored blanks containing colloidal sulfur and a solution of cholesterol in CCl_4 sufficiently diluted to give a levo-rotation similar to the meteorite extracts. The optical rotations of the three, identically prepared saponified fractions from the three different Orgueil stones were measured at three laboratories by three independent investigators. All measurements gave the same results within the limits of known instrumental error. The measurements, and particularly those made at lower wavelengths, were significantly higher than the instrumental error. The results are shown in Table I and Figure 7. The meteorite saponified fractions were levo-rotatory (best noticeable at 435 m μ wavelength) whereas those of the controls (museum dust, museum wax, soil and pollen) were dextro-rotatory at the same wavelengths. The algae and the naphthenic acids showed a slight dextro-rotation or no optical activity. Laboratory contaminations, evaluated by special control runs, also indicated dextro-rotation. Bruderheim showed no optical activity. Generally, both the levo and the dextro-rotations appeared to increase toward lower wavelengths; a levo-rotation of $-0.023^\circ \pm 0.005^\circ$ was obtained for Orgueil at 435 m μ , next to the lower limit of optical transparency of the acidic meteorite solutions. During this study colored solutions and suspensions of colloidal sulfur were examined, samples were filtered through Millipore filters, cell design, length, instruments, and instrumental conditions were varied; these procedures indicate that the measured optical activity in Orgueil was real.

DISCUSSION

Earlier attempts to detect optical rotation in carbonaceous meteorites (23, 24) have been unsuccessful. It appears that this can be explained by some of the following factors: (a) by the use of polarimeters lacking sufficient sensitivity, (b) by the use of chemically unfractionated organic matter or by the study of the chemical fractions in which optical rotation was either absent or below the detection limit. It appears that a thorough fractionation of the organic matter is essential for the detection of optical rotation in Orgueil, because of the probable presence of compounds having varying (or opposing) rotation. Finally, it is possible that previous failure to detect optical activity is also related to (c) the opacity of solutions at the lower spect-

ral range and to the apparent restriction of some of the easily detectable rotation to a narrow range right adjacent to this lower limit of transparency.

The optical activity in organic substances synthesized in enzymatically catalyzed processes arises from asymmetry associated with the presence of at least one carbon atom in the molecule to which four different groups are bonded. Other types of asymmetry in organic molecules are seen in allene, spirane, biphenyl and certain polycyclic aromatic systems. Laboratory synthesis of compounds with asymmetric centers gives racemic mixtures. The ordinary source of optically active material of natural occurrence, however, is in the asymmetric synthesis catalyzed by enzymes produced by living cells. The authors are not aware of naturally occurring optically active terrestrial organic substances which have been demonstrated to have any other origin. The synthesis of optically active compounds in contact with surfaces of enantiomorphous crystals has not been conclusively demonstrated, (25, 26). It seems reasonable to connect optical rotation in Orgueil with biological activity, either of indigenous origin or perhaps still related to terrestrial contaminations.

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REFERENCES

1. Cloëz, S., Compt. rend. Acad. Sci., Paris, 58, 986 (1864) and ibid., 59, 37 (1864).
2. Berthelot, M., Compt. rend. Acad. Sci., Paris, 67, 849 (1868).
3. Nagy, B., Meinschein, W. G. and Hennessy, D. J., Ann. N. Y. Acad. Sci., 93, 25 (1961).
4. Meinschein, W. G., Nagy, B. and Hennessy, D. J., Ann. N. Y. Acad. Sci., 108, 553 (1963).
5. Nagy, B. and Bitz, M. C., Arch. Biochem. Biophys., 101, 240 (1963).
6. Hodgson, G. W. and Baker, B. L., Nature (in press).
7. Claus, G. and Nagy, B., Nature, 192, 594 (1961).
8. Staplin, F. L., Micropaleontol., 8, 343, (1962).
9. Nagy, B., Fredriksson, K., Urey, H. C., Claus, G., Andersen, C. A. and Percy, J., Nature, 198, 121 (1963).
10. Nagy, B., Fredriksson, K., Kudynowski, J., and Carlson, L., Nature, 200, 565 (1963).
11. Nagy, B., Meinschein, W. G. and Hennessy, D. J., Ann. N. Y. Acad. Sci., 108, 534 (1963).
12. Wiik, H. B., Geochim. et Cosmochim. Acta, 9, 279 (1956).
13. Boato, G., Geochim. et Cosmochim. Acta, 6, 209 (1954).
14. Nagy, B. and Claus, G., Proc. Conf. Organic. Geochemistry, Milan, (Pergamon Press, in press).
15. Oakwood, T. S., Shriver, D. S., Fall, H. H., McAleer, W. J. and Wunz, P. R., Ind. Eng. Chem., 44, 2568 (1952).
16. Pictet, A., Ramseyer, L. and Kaiser, O., Compt. rend. Acad. Sci., Paris, 163, 358 (1916).
17. Anders, E. and Fitch, F. W., Science, 138, 1392 (1962).
18. Fitch, F. W. and Anders, E., Ann. N. Y. Acad. Sci., 108, 495 (1963).
19. Dasler, W. and Bauer, C. D., Ind. Eng. Chem., 18, 52, (1946).
20. Bleyberg, W. and Ulrich, H., Ber., 64, 2504 (1931).
21. Shreve, O. D., Heether, M. R., Knight, H. B. and Swern, D., Anal. Chem., 22, 1498 (1950).
22. Flett, M. St. C., J. Chem. Soc., 962 (1951).
23. Mueller, G., Geochim. et Cosmochim. Acta, 4, 1 (1953).
24. Kaplan, I. R., Degens, E. T. and Reuter, J. H., Geochim. et Cosmochim. Acta, 27, 805 (1963).
25. Schwab, G. M., Rost, F. and Rudolph, L., Kolloid. Z., 68, 157 (1934).
26. Ulbricht, T. L. V., Compar. Biochem., 4, (B), 18 (1962).
27. Sobotka, H. and Stynler, F., J. Am. Chem. Soc., 72, 5139 (1950).

TABLE I. OPTICAL ROTATION OF SAPONIFIED FRACTIONS ISOLATED FROM THE ORGUEIL METEORITE AND CONTROLS

Values in degrees refer to solvent standards*

Wave length μ	(a) Orgueil 1	(b) Orgueil 2	(c) Orgueil 3	(d) Bruderheim	(e) Procedure Blanks	(f) Museum Dust	(g) Museum Wax	(h) Ragweed Pollen 1	(i) Ragweed Pollen 2	(j) Soil 1	(k) Soil 2	(l) Brown Algae	(m) Naphthalenic Acid
306	-	-	-	-	-	-	..	-	-	-	-	-	-
353	-	-	-	..	+0.003	-	..	-	+0.023	-	-	-	-
390	-	-	-	..	+0.005	-	..	-	+0.023	-	+0.030	-	-
406	-	-	-	..	0.000	-	..	-	+0.026	-	+0.030	-	-
435	-	-	-0.023	0.000	+0.003 -0.001	-	+0.043	-	+0.019	-	+0.015	+0.002	+0.002
440	-0.020	-	..	..	+0.003	-	..	-	+0.023	-	+0.016	..	..
450	..	-0.012	..	..	+0.003	-	..	+0.003?	+0.023	-	+0.014	..	..
475	..	..	..	..	+0.003	-	..	..	+0.021	-	+0.010	..	..
500	..	-0.007	..	-0.001	+0.003	-	..	+0.016	+0.023	-	+0.014	+0.004	0.000
550	..	..	..	..	+0.003	-	..	..	+0.023	+0.025	+0.014	..	..
570	..	..	..	..	+0.004	+0.124	..	..	..	+0.025	+0.016	..	..
589	..	-0.007	..	0.000	+0.001 -0.004	+0.121	..	+0.011	..	+0.025	+0.018	+0.004	0.000
595	..	..	-0.008	..	..	..	+0.048	..	..	..	..	..	..
600	..	..	..	..	+0.000 +0.001	..	..	..	+0.020	+0.026	+0.016	..	..
620	..	..	..	..	0.000	+0.116	..	..	..	..	+0.015	..	..
650	..	-0.008	..	+0.001	-0.004	+0.102	..	+0.012	..	..	+0.017	+0.004	0.000
Range of Error	+0.005	+0.005	+0.005	+0.005	+0.005	+0.005	+0.005	+0.005	+0.008	+0.005	+0.008	+0.005	+0.005

*All measurements were made at room temperature. The concentrations of organic fractions were of the same order of magnitude except the museum wax solution which was more concentrated; however, exact values are not known because of the presence of some sulfur in the Orgueil extracts. The figures presented here refer to measurements made in cells of the same lengths. Variation in cell lengths caused corresponding variations in optical rotation values. Measurements a, e, i, and k were made at the University of Pisa; b, d, e, f, k, j, l and m at Brandeis University; and c and g at California Research Corporation

Symbols: - no transmittance
.. not measured

CAPTIONS FOR ILLUSTRATIONS

Figure 1

A stone of the Orgueil meteorite (Orgueil sample No. 3) before its surface was removed with a specially cleaned drill. Optically active organic matter was isolated from the interior of this stone. The burnt crust is located between the arrows.

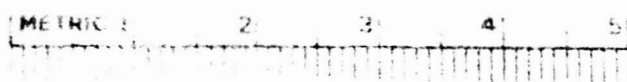


Figure 2

Absorption curves in the visible spectral range of an Orgueil saponified fraction and synthetic colored blank containing sulfur. The optical rotation of one Orgueil fraction was measured against this blank. Arrow indicates the wavelength where the optical rotation of Orgueil is best noticeable.

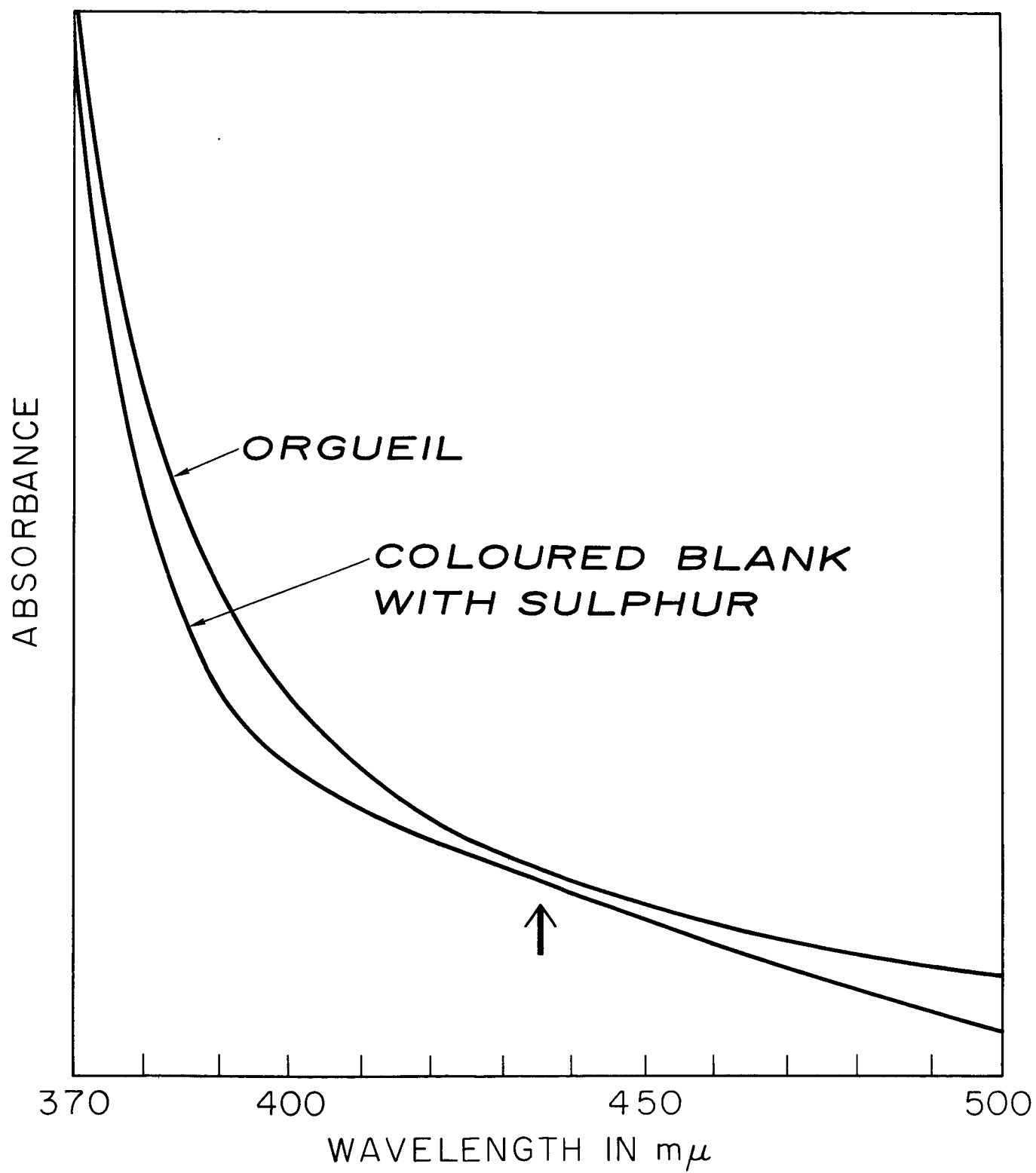


Figure 3

Infrared spectra of saponified organic fractions from the Orgueil meteorite and controls. Curve H is taken from the literature (27). Spectral features characteristic of carboxylic acids are at 3.3, 3.7, 5.85, and 10.5 μ .

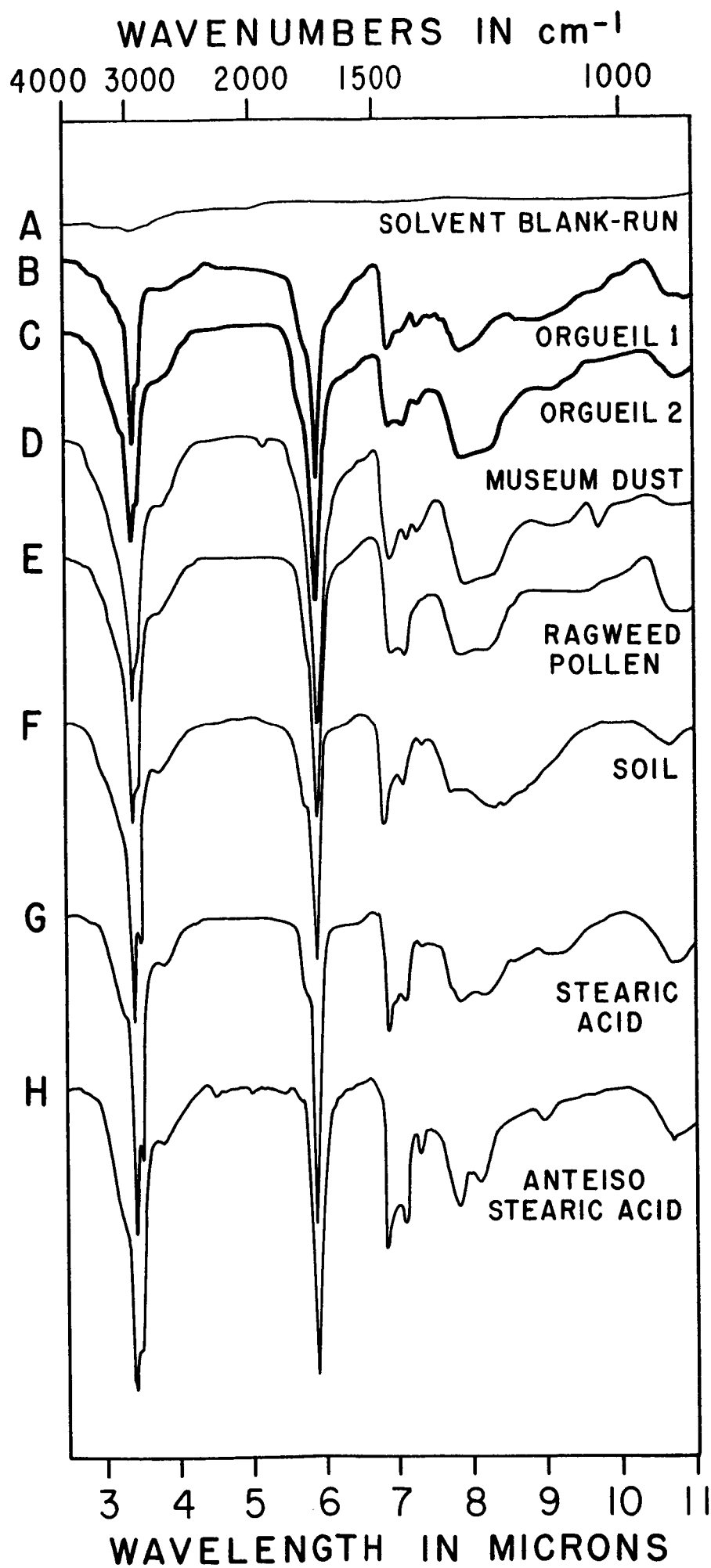


Figure 4

Infrared spectra of saponified organic fractions from the Orgueil meteorite and controls.

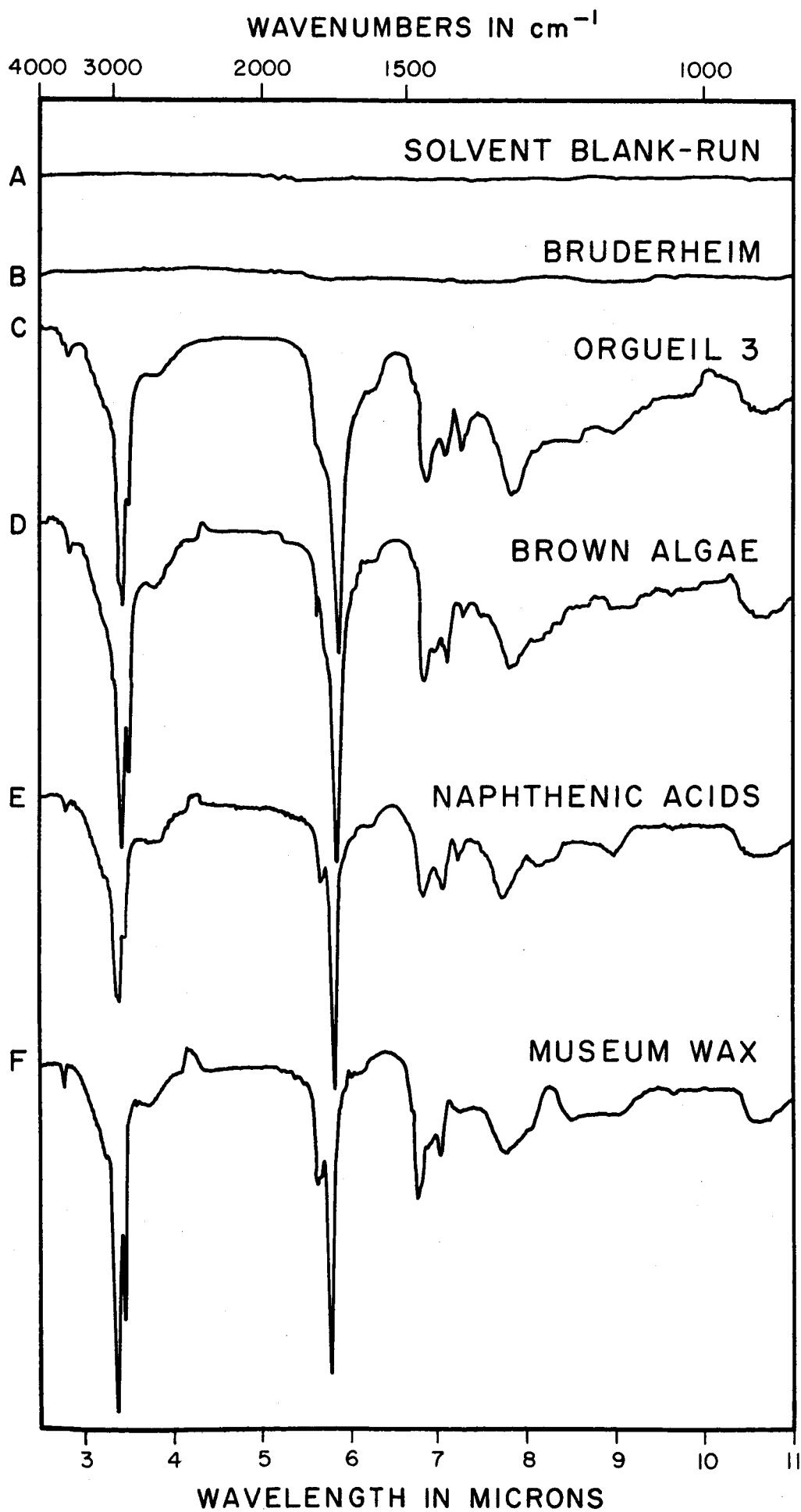


Figure 5

Ultraviolet spectra of saponified organic fractions from the Orgueil meteorite and controls. Arrows show the absorption bands. The Orgueil absorption bands (solid arrows and dashed lines) are not located at the same wavelengths as those of the controls.

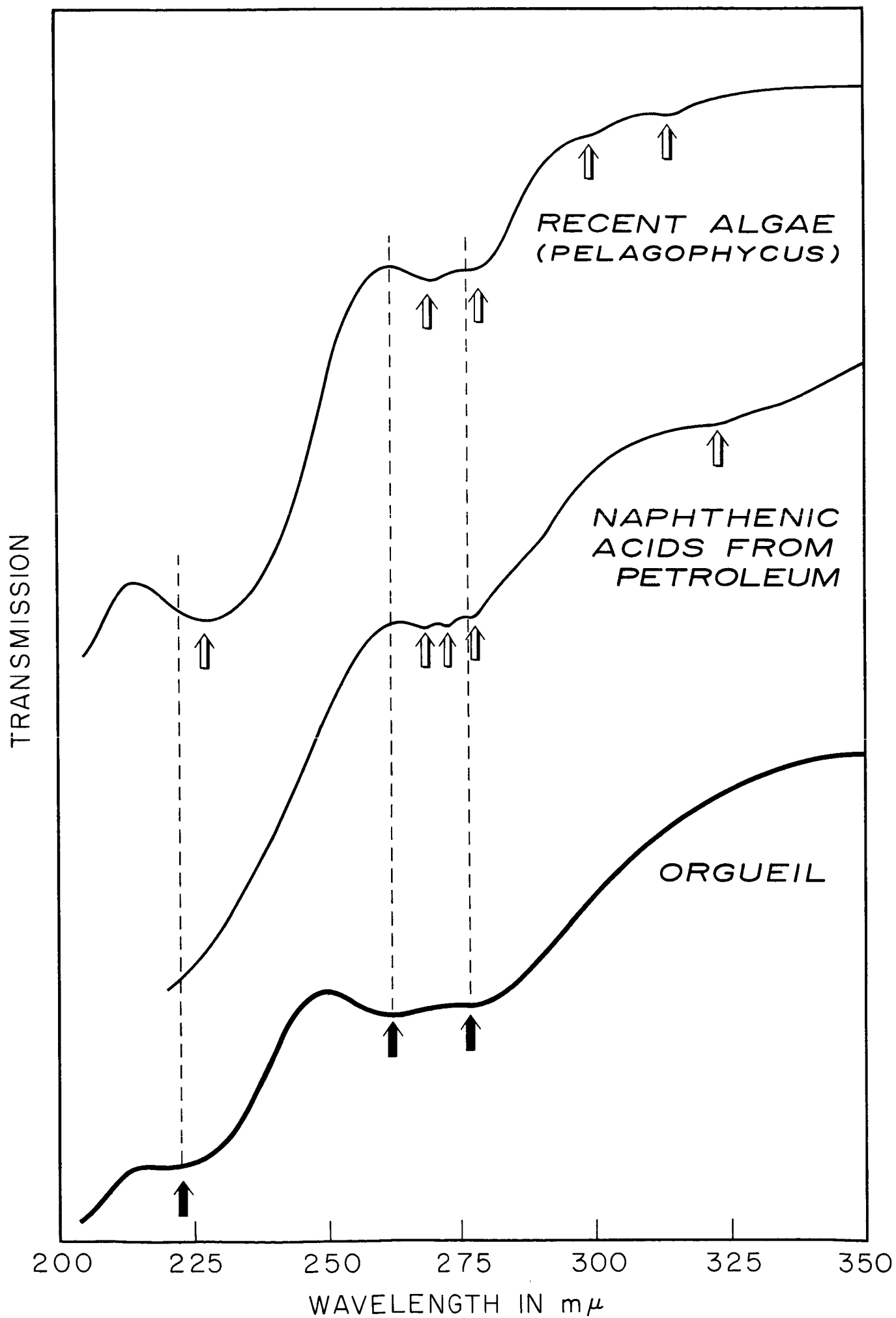
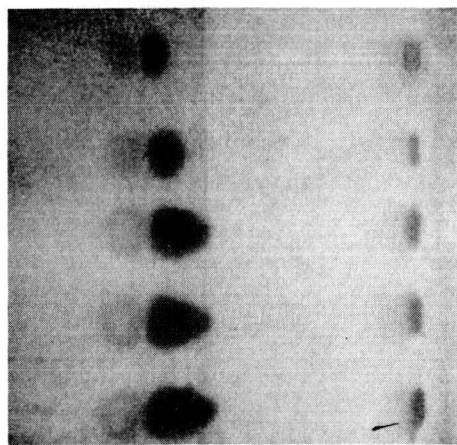
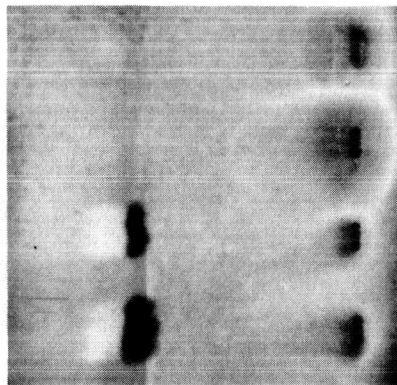


Figure 6a,b,c

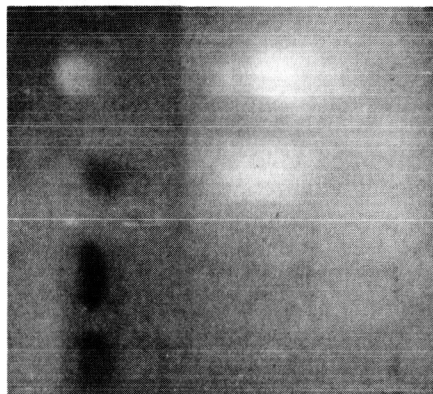
Thin layer chromatograms on silica gel and calcium sulfate or magnesium silicate taken in ultraviolet light after rhodamine 6G staining of saponified organic fractions from the Orgueil meteorite and controls. Figure 6a shows a plate developed with a solution of n-hexane-ether (97/3, v/v); 6b with a solution of n-hexane-ether (95/5, v/v and 6c with a solution of chloroform-methanol-water (65/25/4, v/v/v). Rows A, B and C show the three main components of the Orgueil fractions; A hydrocarbons, B sulfur and C acidic compounds. Columns 1-7, 10-11 are Orgueil saponified fractions, 8 and 12 are saponified naphthenic acids, 9 and 13 are saponified matter from brown algae. Note the absence of natural lipids in the Orgueil samples. These lipids are visible between rows B and C in naphthenic acids and algae (columns 8, 9, 12 and 13).



A.



B.



C.

1 2 3 4 5 6 7 8 9 10 11 12 13

a.

b.

c.

Figure 7

Optical rotation of saponified extracts from the Orgueil meteorite and controls. Vertical lines show the range of experimental error. Different symbols on the Orgueil curve refer to measurements made at different laboratories. The optical rotation of brown algae, naphthenic acids and Bruderheim non-carbonaceous meteorite fall in the range of the blanks.

